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EFFECTS OF EXERCISE AND DIETARY PROTEIN LEVELS ON BODY COMPOSITION IN HUMANS

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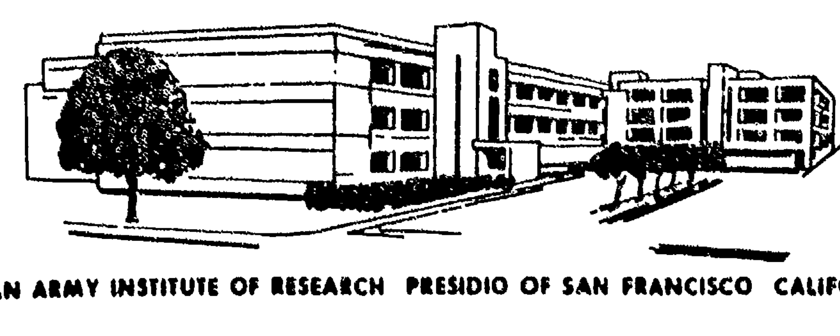

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Two levels of protein (200 and 100 gm/day) were fed to two groups of young adults who exercised strenuously for 40 days. From body volume, total body water mass, ^{40}K whole body counting, and potassium balances, it was determined that the 2.10 kg gain in body weight in Group I subjects (200 gm of protein/day) reflected 0.67, 2.42, and 0.22 kg gains of dry protein, water, and mineral, respectively, with a 1.21 kg loss of body fat. Lesser gains of 0.39 kg of dry protein, 1.46 kg of body water, and 0.13 kg of mineral were observed in Group II, with a 1.09 kg

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20. Abstract (cont)

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ABSTRACT

Two levels of protein (200 and 100 gm/day) were fed to two groups of young adults who exercised strenuously for 40 days. From body volume, total body water mass, ^{40}K whole body counting, and potassium balances, it was determined that the 2.10 kg gain in body weight in Group I subjects (200 gm of protein/day) reflected 0.67, 2.42, and 0.22 kg gains of dry protein, water, and mineral, respectively, with a 1.21 kg loss of body fat. Lesser gains of 0.39 kg of dry protein, 1.46 kg of body water, and 0.13 kg of mineral were observed in Group II, with a 1.09 kg loss of body fat. Minimal changes were noted in several anthropometric girths, and arm and scapular skinfolds. Although higher dietary protein intakes resulted in small increments in nitrogen and potassium retentions, intakes of 100 grams of protein per day were sufficient for positive nitrogen balances and appeared to be adequate for men during strenuous physical activity.

PREFACE

Mr. Harry J. Krzywicki retired from Federal Service and presently lives in Aurora, Colorado.

Mr. C. Frank Conzolazio, world renowned physiologist and nutritionist, died while still in Federal Service on 23 December 1976. His dedication to scientific endeavors, encouragement to co-workers and subordinates, and his great initiative in research are sorely missed by all of his friends and associates.

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INTRODUCTION

Irwin and Hegsted (1) discussed the elusiveness of determining the protein requirements of man as well as the lack of precision in evaluating nutritional status, particularly as it is affected by age, sex, physical activity, and stress. Early workers (2-6) estimated that protein requirements ranged from 30 to 125 gm/day; however, it was eventually accepted that one gram of protein per kilogram of body weight provided a safety margin for all individuals (7). The need for body composition studies to identify the protein compartment was evident.

Early in the century, the beneficial effects of low protein intakes of 50 to 60 gm/day upon physical fitness were reported (8); however, later work (9) indicated that no differences were found in men consuming between 50 and 160 gm of protein daily. Anemia and hypoproteinemia were demonstrated during heavy exercise with positive nitrogen balance on a 60 gm daily intake of protein (10). Conversely, slightly negative nitrogen balances were reported during exercise with intakes of 0.71 gm of protein/kg of body weight, and blood components were unchanged (11). However, serum protein, hemoglobin, and body cell mass did decrease when intake was further lowered. It was also reported that muscle protein was synthesized at the expense of blood protein on intakes of 1.0 to 1.5 gm of protein/kg of body weight, but,

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2. Voit, C. Ztschr Biol 2:307, 1866
3. Atwater, W.O. Fifteenth Annual Report. Storrs Agriculture Experimental Station, 1903
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11. Rodriguez, H.B. Heavy Dynamic Work and Protein Requirements in man. Ph.D. Thesis. Cambridge, MA: MIT, 1968

again, specific and complete body compartment studies were lacking (12). Another report cited that deterioration of physical performance occurred on 0.6 gm of egg protein per kg of body weight (13), with concomitant losses of body potassium in three of five subjects. Recently, Torun et al (14) confirmed the losses of body potassium during exercise in subjects consuming diets containing 0.5 gm of protein/kg of body weight, and reported that this could be alleviated by excluding exercise, increasing dietary protein to 1 gm/kg of body weight, or by increasing caloric intakes.

The controversy of whether or not increased physical work increases protein requirements continues. With present day emphasis on physical fitness, health, and prevention of disease, this problem needs to be resolved. Many groups require information on the metabolism of protein during physical training, and, particularly, body composition and protein compartment alterations. The athlete and trainer believe that additional dietary protein is needed for muscle development, and the Armed Forces are concerned with developing and maintaining physical fitness in troops, especially during basic training. It is possible that an increase of muscle mass through biosynthesis of protein may occur during strenuous physical activity, and this protein synthesis requires additional dietary protein to prevent the utilization of labile protein stores. Athletes are particularly imbued with the concept that physical training and heavy physical activity require additional dietary protein.

An increase in the NRC recommended allowances may be a practical solution; however, little information is available on the need for increased dietary protein during physical conditioning. Many eminent nutritionists advocate a reduction in protein consumption to reduce the incidence of cancer, heart disease, and other "killer" diseases. These studies have included some aspects of body ergometrics (11, 14, 15) and body compartments in an effort to relate protein retention to changes in body tissue mass; however, continued effort is indicated.

The objective of this study was to assess the effects of 100 and 200 gm of protein intake upon changes in body composition (namely, protein, fat, and water) and to observe protein retention in young adult males while undergoing extensive physical training over an extended period. Such training may induce changes in muscle compartment, indicative of protein retention with concomitant fat losses and increased hydration of the body.

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12. Yamaji, R. J Physiol Soc Japan 13:476, 1951
13. Tandon, B. et al. Fed Proc 28:494, 1969
14. Torun, B. et al. Am J Clin Nutr 30:1983, 1977
15. Das, B.B. Body Composition and Work Performance with Respect to Protein Nutriture: A Study in Young Men. Ph.D. Thesis, Cambridge, MA: MIT, 1967

METHODS

The subjects were 8 healthy young adult males (mean age 21 years) who consumed a 3,000 kcal liquid control diet (Table 1) for 6 days while preliminary body composition measurements were being made. Body composition measurements techniques have been described elsewhere (16) and include body densitometry by water displacement, total body water from deuterium dilution, "thiocyanate space" from sodium thiocyanate dilution, body potassium from whole body counting of ^{40}K and various anthropometric girths, diameters, and skinfold thicknesses. The men were randomly divided into two equal groups. The first group (I) of 4 men was issued a 3,700 kilocalorie diet containing 200 gm of protein while the second group (II) received the same calorie intake with 100 gm of protein (Table 1). Then a rigorous exercise schedule was conducted for 40 days to evaluate the effects of training on protein requirements. The exercise program was conducted for 5 to 6 hours per day, six days each week, and included calisthenics, isometric-isotonic activities, running, treadmill and ergometer exercises, and sports activities. Although the program was designed to increase physical fitness, these subjects were well conditioned prior to the study and only minimal improvement occurred. The body composition measurements were made on the 12th, 19th, 26th, 33rd, and 40th days of the study.

Statistical analyses were conducted using analysis of variance and "paired-t" tests which are strongly influenced by consistence of change among subjects. Significance was tested at the 5% probability level.

RESULTS

Table 2 presents the observed mean changes in body density, body weight, and the derived values for the fat, water, protein, and mineral compartments of the two groups. In Group I, body density was increased 0.005 gm/ml of volume over control values by day 26, and remained essentially unchanged through day 40. Body weight increased steadily during the experimental period (total of 2.11 kg/man), while body fat stores were being reduced. The 1.40 kg fat loss on day 26 was significant. Significant increases of 2.42 kg of body water, 0.67 kg of dry protein, and 0.22 kg of body minerals were observed by day 40. Lesser changes were observed in Group II with significant increases by day 40 for only dry protein, 0.38 kg, and mineral, 0.13 kg. The increases of 0.003 gm/ml in density, 0.83 kg of body weight and 1.40 kg of body weight, and loss of 1.09 kg of fat at this time were consistent with each other and the changes in protein and mineral, but were not statistically significant.

The total body potassium values obtained from ^{40}K counting and derived compartments for lean body mass, fat, and dry protein are shown in Table 3. The gain of 6.05 gm of potassium observed in Group I

16. Krzywicki, H.J., et al. Am J Clin Nutr 27;1380, 1974

indicated a 2.27 kg gain of lean body mass, 0.16 kg loss of fat, and a 0.46 kg gain of dry protein by day 40. In Group II the total body potassium and subsequently dry protein and lean body masses were essentially unchanged by day 40; however, body fat stores had increased by 0.74 kg.

The observed changes in total body water (D_2O dilution), extracellular water by sodium thiocyanate dilution, and water balances are presented in Table 4. Total body water was increased by 6.3 kg at day 40 while extracellular water increased by only 0.6 kg in Group I. Water balance, calculated from weight changes and weights of intakes and excretions, was positive at 2.89 kg. Group II total body water had steadily increased by 5.4 kg by day 40 with a loss of 0.2 kg of extracellular water. Water balance in this group was also positive by 0.22 kg at day 40.

Nitrogen and potassium balances were calculated on a period basis (Table 5). Group I subjects had positive nitrogen balances throughout the study; however, the greatest retention was during days 1-12, which suggests that muscle mass was increasing during the initial training period. Total nitrogen retention was 62.89 gm, equal to 0.39 kg of dry protein, or 1.46 kg of body muscle tissue. Group II subjects lost a small amount of nitrogen during the control phase, and then the balances were positive throughout the training period. Total retention was 21.96 gm, approximately one-third of the total for Group I. Body potassium balances were positive for both groups of subjects, except for negative balances observed during the control phase of Group I. Potassium balances were steadily decreased in both groups during the experimental phase of the study and total retention was 27.98 gm and 23.67 gm of potassium, respectively, for Groups I and II.

Table 6 shows changes in several anthropometric measurements for the subjects of Groups I and II. A slight but significant increase was noted for Group I subjects in the mean forearm girth at day 33 of the experimental period, while the biceps showed a slight but significant increase in girth on days 12, 26, and 33. The calf showed a significant increase on days 12 and 33, yet increases in the waist circumferences were insignificant as were the minor changes noted in the buttock circumferences. Group II showed significant increases only for the biceps on days 12, 19, 33, and 40, while the calf showed a significant increase on day 12. The forearm, waist, and buttock circumferences showed no significant changes from control values.

Table 7 lists mean changes in the triceps and scapula skinfolds, and it is readily noted that although decreases in triceps skinfold in both groups occurred, the variations were too great to show significance. The scapula skinfold thickness decreased on day 40 in Group I, and increased slightly in Group II.

DISCUSSION

Body weight changes should reflect changes in water, fat, protein, and mineral compartments. These compartments were examined from several aspects; the first was the estimation of the body fat load from water displacement densitometry. By difference, the fat-free mass of the body was then calculated and further partitioned into the water, protein, and mineral compartments from various constants proposed by Allen (17). Body weight changes are poor predictors of the aforementioned compartments, and fat is usually the first variable affected when diet or energy expenditure is manipulated. Body potassium is a good indicator of lean body mass, and the aforementioned constants were again applied to determine protein mass, etc. Nitrogen and potassium balances were also used to estimate changes in the protein compartment.

It can be noted from Table 2 that higher protein intake resulted in a greater nitrogen retention from several aspects. Densitometrically, the dry protein compartment (muscle and non-muscle) was significantly increased by 0.67 kg for the subjects consuming 200 gm protein/day. Body water was increased with an increase in body weight and a concomitant loss of body fat in both groups; however, only the increase in Group I's body water was significant. Only dry protein and mineral components of Group II were significantly increased at the end of the study; but all changes in body compartments were greater on the 200 gm of protein intake.

From ^{40}K counting (Table 3), the 6.05 gm increase of body potassium reflected a 0.46 kg increase of dry protein in Group I (1 gm K = 0.076 kg dry protein) at 40 days. Actually, an 8.8 gm increase of K would be required to equal the increase of the dry protein compartment noted from body density. The unchanged values for potassium of Group II reflect the low sensitivity of ^{40}K counting for detecting small changes in body potassium stores. The discrepancies between density derived and ^{40}K-derived values for fat and lean body masses have been reported (16). The increase of 27.98 and 23.16 gm of K (Table 5) from the balance study for Groups I and II, respectively, overestimate the changes in the dry protein compartment, i.e., the K retentions would indicate protein increases of 2.13 kg in Group I and 1.80 in Group II.

The nitrogen balance data in Table 5 show retention of 62.89 gm in Group I and 21.96 gm in Group II subjects, or approximately 0.39 and 0.14 kg of dry protein respectively (6.25 gm of protein per gm of N). The data for Group I resemble that of ^{40}K counting and were about one-half of the values derived from body density. Body density is favored at this laboratory as being most accurate for estimating body compartments, since a recent comparison of techniques for extracting body composition showed densitometry to be more accurate than ^{40}K counting or total body water measurements (16).

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17. Allen, T.H.A., et al. J Appl Physiol 14:1009, 1959

Das (15) measured body water and potassium to estimate body cell mass as an index of protein retention while feeding 0.8 gm of protein and either 35 or 50 kcal/day/kg of body weight to subjects doing dynamic work. Slight gains in body weight were noted in the 50 kcal/kg group during the study; however, exercisers at either calorie level lost weight during specific work phases of the study (3.4% of body weight at 35 kcal/kg vs. 1.7% at 50 kcal/kg).

With isometric exercise, Das (15) showed subjects receiving 0.59 gm, 0.71 gm, or 0.80 gm of protein/kg of body weight gained or lost 0.60 kg during the study, but did not attempt to relate the weight changes to diets because of the great variance. Only one subject showed an increase in body cell mass.

Watkin and Miller (18) studied adolescents with malignant disease who were fed 1.8 gm of protein and 50 kcal/kg of body weight per day. The workload was 10 to 30% of their calorie intake. Nitrogen retention was observed in all subjects and respiratory quotients were reduced during exercise, but no body compartment changes were reported.

Rodriguez (11) attempted body composition studies in 10 subjects fed 0.71, 0.50, or 0.39 gm of protein/kg of body weight with adequate calories for maintenance for 24 days, and reported small weight losses between 200 and 500 gm during the work phase of the study. One subject lost 1200 gm on the 0.71 gm diet, while another lost 3000 gm on the 0.39 gm of protein intake, but the composition of the weight loss was not evaluated.

Torun (19) conducted long-term studies of 5 adult male populations with intakes ranging from 58 to 112 gm of protein and 1800 to 3300 kcal/day and observed no overt signs of malnutrition or obesity. Body composition of subjects on the lower protein to calorie ratios showed the effect of a calorie deficit but no decrease in lean body or muscle, which suggested an adaptation to the lower protein intakes for active subjects on low protein intakes as compared to a lesser lean mass for those on high protein and calorie intakes with reduced physical activity.

The derived changes in body water of subjects in our study showed a 2.42 kg mean gain in Group I and a 1.46 kg of gain in Group II. Rodriquez (11) found losses of 1.3 kg of water for men receiving diets containing 0.39 gm of protein per kg of body weight, a 1.6 kg of water loss at 0.59 gm of protein/kg and for 2 subjects receiving 0.71 gm/kg per day, one gained 1.2 kg and the other lost 1.6 kg of water during

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18. Watkin D.M., and B.S. Miller. Fed Proc 18:167, 1959
19. Torun, B., et al. Fed Proc 27:679, 1968

the study. Apparently, there may be a trend for water retention with an increase of dietary protein as is reported here. If muscle mass is increasing, a gain in body water with a loss of body fat can be expected.

Rodriquez (11) noted significant losses of 11% of the extracellular body water at low levels of protein intake (0.39 and 0.50 gm/kg of body weight) and unrelated changes at 0.7 gm. Extracellular water in our study was increased 1.3 kg in Group I after the training period, and then remained between 16.7 and 17.0 kg for the balance of the study. Group II showed a loss of 0.2 kg at day 40. Similar insignificant changes in this compartment were reported by Das (15) who also considered them inconsequential.

Das (15) used ^{40}K counting to determine body protein changes in subjects undergoing isometric exercises. Two men receiving 0.7 and 0.8 gm of protein/kg of body weight had significant increases in cell mass, but those who received only 0.5 gm/kg had a reduction of the body cell mass. Our calculation of the dry protein mass from densitometry showed an increase of approximately 5.3% in the high-intake group.

The derived changes in the mineral content may also suggest that more K was retained by the subjects on their relatively high protein intakes. No densitometric values are available in the literature for comparison with the present study.

The nitrogen balances were positive for both groups during the entire study; however, the greater retention occurred in the high protein group and this was due to the high intake. It appears that protein was conserved when 100 gm were fed. Excretions of Group II subjects were reduced 14% in feces, 37% in sweat, and 51% in the urine in comparison to Group I men. Das (15) also observed a greater percentage of nitrogen retention in subjects consuming diets with lower levels of protein. He found nitrogen equilibrium at the 0.8 gm/kg level, and half of the subjects receiving 0.7 gm of protein/kg of body weight were in equilibrium, while negative balances were observed in those receiving 0.5 gm/kg.

The increased urinary output of nitrogen in Group I was expected and was also observed by Rodriquez (11) as opposed to the constant nitrogen output in Group II. Sweat nitrogen was slightly reduced in Group I by day 24, but appeared to be within normal limits. This was also noted in Group II. Das (15) did not collect sweat in his study, and his estimated values appear to be unrealistic.

Rodriquez (11) reported positive balances of K in subjects on 0.71 and 0.59 gm of protein/kg diets, while negative balances were seen in subjects on 0.39 gm, but he was reluctant to accept these values since they are at best estimates including arm bag sweat collection techniques.

Only a few significant changes in body anthropometry were noted, including increases in the biceps at days 12, 26, and 33, and the calf circumferences on days 12 and 33 in Group II. A similar pattern was noted for Group I. With the mean weight gain observed for these groups, one would expect Group I to have had slightly larger girths by the end of the study, but these are probably difficult to observe in exercising men for this short a period. The skinfold thicknesses simply did not show any significant change, regardless of diet and exercise, and, in this instance, were poor indicators of changes in body compartments, mainly fat in the subcutaneous tissues.

The results of this study showed that increased dietary protein increased nitrogen, potassium, and protein retention during strenuous physical activity. However, only a small amount of extra protein was retained; the balance of the nitrogen was excreted. The men receiving 100 gm of dietary protein per day maintained positive nitrogen balance and, apparently, were able to increase muscle mass. Therefore, 100 gm of protein per day appeared to be adequate for these men and most of the dietary protein in excess of this was converted to energy sources. Animal protein calories are expensive; while vegetable protein calories are less expensive, they provide an excess of carbohydrate calories in addition to protein calories.

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APPENDIX

Table 1. Two levels of protein intake; diet composition.

	Kcalories	Protein	Fat	Carbohydrate
Control (all men)	3084	103.3 gm (13.4%)*	136.8 gm (39.9%)	359.9 gm (46.7%)
Group I (200 gm intake)	3766	204.5 gm (21.7%)	144.9 gm (34.4%)	412.9 gm (43.9%)
Group II (100 gm intake)	3762	103.3 gm (11.0%)	161.8 gm (38.7%)	473.1 (50.3%)

*Percent of calories

Table 2. Changes in body composition during two levels of protein intake (mean ± S.D.)

	Control	Group I Experimental (days) 12	19	26	33	40
Density gm/ml	1.080 ± 0.014	1.080 ± 0.010	1.080 ± 0.010	1.085 ± 0.012	1.085 ± 0.020	1.084 ± 0.010
Weight kg	70.48 ± 10.0	71.89 ± 9.18	71.66 ± 8.79	72.15 ± 8.24	72.57 ± 7.94	72.59 ± 7.67
Fat kg	8.06 ± 4.56	8.15 ± 3.42	8.14 ± 3.96	6.66^a ± 4.16	6.63 ± 3.25	6.85 ± 3.53
Water kg	45.56 ± 4.52	46.50 ± 4.94	46.37 ± 4.45	47.81^a ± 3.94	48.13^c ± 4.30	47.98^b ± 3.62
Dry Protein kg	12.60 ± 1.26	12.96^a ± 1.32	12.83 ± 1.23	13.22^a ± 1.09	13.32^c ± 1.19	13.27^c ± 1.00
Mineral kg	4.24 ± 0.42	4.33 ± 0.46	4.32 ± 0.46	4.45^a ± 0.36	4.48^a ± 0.40	4.46^a ± 0.34
			Group II			
Density gm/ml	1.078 ± 0.010	1.074 ± 0.010	1.076 ± 0.012	1.078 ± 0.014	1.077 ± 0.014	1.081 ± 0.014
Weight kg	72.15 ± 6.61	72.92 ± 7.02	72.81 ± 7.10	72.94 ± 6.91	72.95 ± 6.78	72.98 ± 6.67
Fat kg	8.98 ± 4.81	9.98 ± 4.84	9.66 ± 4.63	8.78 ± 4.85	9.35 ± 5.23	7.89 ± 4.64
Water kg	46.11 ± 1.60	45.94 ± 1.66	46.10 ± 1.97	46.84 ± 2.35	46.42 ± 2.17	47.51 ± 1.78
Dry Protein kg	12.76 ± 0.50	12.71 ± 0.46	12.75 ± 0.55	12.96 ± 0.65	12.84 ± 0.59	13.14^a ± 0.50
Mineral kg	4.29 ± 0.17	4.28 ± 0.15	4.29 ± 0.18	4.36 ± 0.22	4.32 ± 0.20	4.42^a ± 0.17

a = Significantly different from control value, $p < 0.01$

b = Significantly different from control value, $p < 0.025$

c = Significantly different from control value, $p < 0.05$

Table 3. Changes in body potassium, lean body mass, and dry protein during two levels of protein feeding

	Control	Experimental (days) 19	Experimental (days) 40
	Group I		
Total body potassium, g	150.10	154.80	156.15
Lean body mass, kg	56.37	58.14	58.64
Fat, kg	14.11	13.52	13.95
Dry protein, kg	11.39	11.74	11.85
	Group II		
Total body potassium, g	152.68	154.01	152.93
Lean body mass, kg	57.34	57.84	57.43
Fat, kg	14.81	14.97	15.55
Dry protein, kg	11.58	11.68	11.60

Table 4. Changes in observed total body water, extracellular water, and water balance on two levels of protein intake (mean ± S.D.)

		Experimental					Total
	Control	12	19	26	33	40	Change
				Group I			
Total body water, kg	43.2 ± 3.1	43.5 ± 2.61	46.8 ± 2.7	46.9 ± 0.8	49.0 ± 4.0	49.5 ± 2.4	6.3
Extracellular water, kg	16.1 ± 2.0	17.4 ± 3.5	16.8 ± 2.0	16.8 ± 1.6	17.0 ± 0.8	16.7 ± 1.7	0.6
Water balance, kg*	+2.45	+1.10	+1.08	-0.55	-0.49	-0.70	2.89
				Group II			
Total body water, kg	45.56 ± 1.50	45.24 ± 2.24	46.96 ± 2.85	49.12 ± 2.18	49.63 ± 1.45	50.96 ± 2.2	5.40
Extracellular water, kg	16.8 ± 0.2	17.2 ± 1.7	16.9 ± 1.4	17.3 ± 1.5	16.7 ± 1.6	16.6 ± 1.4	-0.2
Water balance, kg*	3.84	-0.32	-0.62	-1.05	-0.89	-0.74	+0.22

*Summation of changes for each period and total change is summation for entire period including 10 days of control. These water balances were calculated from weight changes and weights of all intakes and excretions.

Table 5. Nitrogen and potassium balances (gm/man) during two levels of protein intake

	Control	Experimental (days)					Total
	5 days	1-12	13-19	20-26	27-33	34-40	40 days
			Nitrogen				
Group I							
per period	+5.76	+35.76	+11.70	+1.74	+2.53	+11.13	+62.89
per day	+1.15	+ 2.98	+ 1.67	+0.25	+0.36	+ 1.59	+ 1.57
Group II							
per period	-0.48	+ 8.00	+ 4.03	+5.45	+2.94	+ 1.54	+21.96
per day	-0.10	+ 0.67	+ 0.58	+0.78	+0.42	+ 0.22	+ 0.55
			Potassium				
Group I							
per period	-0.48	+10.08	+ 6.68	+5.01	+3.14	+3.08	+27.98
per day	-0.10	+ 0.84	+ 0.95	+0.72	+0.45	+0.44	+ 0.70
Group II							
per period	+0.37	+10.82	+ 3.92	+3.17	+3.48	+2.29	+23.67
per day	+0.07	+ 0.90	+ 0.56	+0.45	+0.50	+0.33	+ 0.59

Table 6. Changes in body circumferences (cm) with two levels of protein intake (mean ± S.D.)

	Control	Experimental (days) 12	19	26	33	40
Group I						
Forearm	26.2 ± 1.1	26.8 ± 0.6	26.6 ± 0.7	26.6 ± 0.9	26.8* ± 0.9	26.8 ± 0.7
Biceps	28.1 ± 2.0	28.8* ± 1.6	28.4 ± 1.6	28.8* ± 1.6	28.9* ± 1.4	28.9 ± 1.3
Calf	36.4 ± 2.8	37.0* ± 2.6	36.9 ± 1.9	36.6 ± 1.8	37.3* ± 1.9	36.9 ± 1.4
Waist	78.6 ± 7.8	78.8 ± 6.8	78.7 ± 5.3	79.0 ± 4.6	79.8 ± 4.0	79.3 ± 4.1
Buttocks	96.2 ± 7.0	95.8 ± 5.5	95.8 ± 5.5	95.6 ± 5.6	95.7 ± 4.2	97.2 ± 1.9
Group II						
Forearm	26.9 ± 0.6	26.9 ± 0.6	26.9 ± 0.2	27.8 ± 0.5	26.8 ± 0.6	26.6 ± 0.6
Biceps	26.8 ± 1.6	28.5* ± 1.0	28.6* ± 1.1	28.5 ± 1.0	28.8* ± 1.0	28.6* ± 0.9
Calf	37.0 ± 2.0	38.7* ± 1.0	38.4 ± 1.3	38.2 ± 1.0	38.4 ± 1.3	38.2 ± 1.4
Waist	78.8 ± 6.5	81.2 ± 5.4	80.8 ± 6.3	80.3 ± 6.0	81.1 ± 6.9	80.5 ± 6.3
Buttocks	95.8 ± 5.5	96.8 ± 4.8	96.7 ± 4.9	97.0 ± 4.5	97.5 ± 4.3	96.7 ± 4.5

*Significantly different from control ($P < 0.05$).

Table 7. Changes (mm) in skinfold thicknesses* on two protein intake levels.

	Control	Experimental (days) 12	19	26	33	40
Group I						
Triceps	8.2 ± 3.7	8.7 ± 4.3	7.7 ± 3.2	8.1 ± 3.8	7.8 ± 3.6	7.7 ± 2.9
Scapula	9.8 ± 2.4	9.9 ± 2.2	9.1 ± 2.0	9.4 ± 2.0	9.4 ± 1.8	9.5 ± 1.8
Group II						
Triceps	9.4 ± 3.6	9.8 ± 2.4	8.9 ± 2.2	9.1 ± 2.3	9.2 ± 3.1	9.2 ± 2.2
Scapula	9.8 ± 3.4	9.6 ± 2.5	9.3 ± 2.6	9.4 ± 3.0	9.5 ± 2.7	9.9 ± 3.0

*Mean of right and left sides, mean ± S.D. of subjects.

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